Silicone Rubber Matrix with Micro-Encapsulated Phase Change Material Filler

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Introduction:

Thermal composites are the by-product of at least 2 materials, one possessing desirable thermal properties, and one possessing desirable mechanical properties. Some such composites include reusable ice packs and carbon nanotube filled epoxy.

In this experiment, the thermal composite is the result of combining a high-temperature vulcanizing silicone rubber (HTV SR) with a commercially available and commercially encapsulated phase change material (PCM). PCM's are any material which possesses the ability to change its physical state, including but not limited to ice, wax, metals, and plastics. What is unique about some specific PCMs is their ability to absorb large quantities of energy during their phase transition. This absorption can be utilized by thermal composites to recover heat-losses and store the energy for later, or to absorb energy which would otherwise bleed from one system to another.

The primary difficulty when working with phase change materials with especially great heat capacities, is they frequently lack a reliable mechanical structure. This is where the mechanical stability provided by the other material in the thermal composite is important. By combining the thermal abilities of a PCM and the mechanical abilities of a stabilizer, a versatile and safe thermal composite can be achieved.

One such thermal composite was attempted by this experiment, which sought to understand the capabilities and limitations of commercially available materials for the express purpose of creating a shape-stable thermal composite.

Methodology:

Testing for this experiment consisted of creating a mock composite material by combining varying amounts of the commercially available, commercially encapsulated PCM with the commercially available SR. The PCM and SR were combined within their mold and baked at 1000C for 15 minutes to cure, as specified in the SR manufacturer's instructions. The samples were then allowed to cool before removal was attempted.

The results of these preliminary experiments revealed a deficiency in the SR's ability to cure with the addition of PCM. The composite's threshold appeared to lie between 10-15% PCM by mass. Any amount of PCM at or beyond 15% by mass resulted in a sample with little to no ability to cure.

Of the 5 samples created (0-15%, and 100% PCM content), all were examined under scanning electron microscope (SEM) in an attempt to understand what reaction may have been occurring to prevent the SR from curing.

Results:

When examined with SEM, the samples containing PCM revealed that the encapsulating material was damaged, and therefore unable to contain the PCM. In low concentrations, the PCM content was not enough to inhibit curing, possibly due to the ratio of PCM:Silicone:Catalyst. When the necessary threshold of PCM was reached, the PCM capsules appeared to have integrated with the silicone and, once ruptured, lost enough of their contents to disrupt the chemical reaction between the silicone and its catalyst. After speaking with the manufacturer of the PCM, it was determined that the heat necessary to cure the SR was responsible for damaging the micro-encapsulating shell surrounding the PCM. When the micro-capsules broke, the PCM leaked from within and inhibited the curing of the SR.

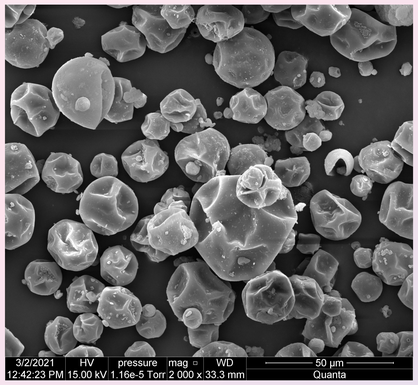

Figure 1 - SEM image of 100% micro-encapsulated PCM. The micro-capsules are observed to have a wrinkled exterior, possibly evidence that the energy of the SEM compromised the micro-capsule's integrity.

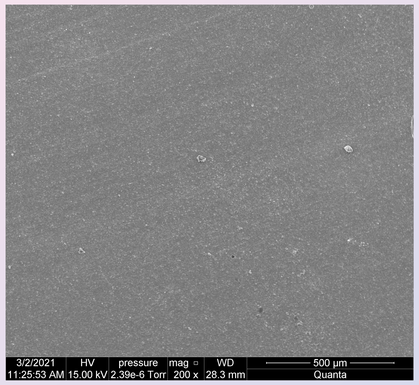

Figure 2 - SEM image of 100% SR. The smooth, fully cured surface serves as a baseline for comparing composite samples against.

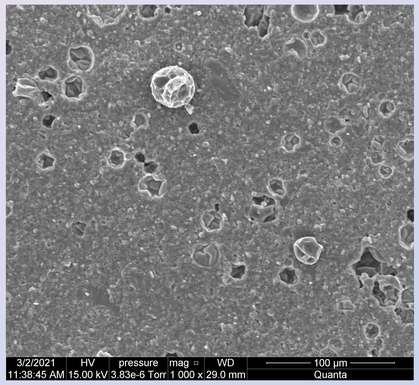

Figure 3 - SEM image of 5% PCM, 95% SR. The surface of the sample has ruptured PCM micro-capsules, and a rough, bumpy appearance. The surface appearance may be a direct consequence of localized cure inhibition. As noted in the image, there are also cavities where PCM micro-capsules appear to have once been.

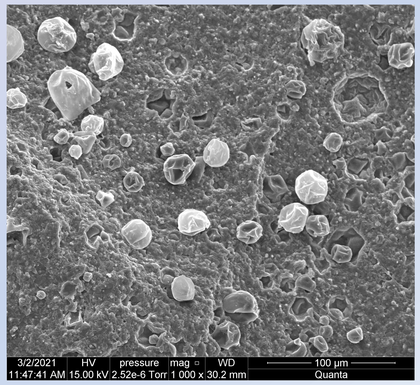

Figure 4 - SEM image of 10% PCM, 90% SR. The surface of this sample has a noticeably increased concentration of PCM micro-capsules when compared to Figure 3 (5% PCM content). As noted in the image, there is a clearly defined tear/rupture point in one of the microcapsules, and this may be a clear demonstration of the damage which occurs when the micro-capsules are heated. The surface of the sample also appears to have a rough finish. This rough finish may be due to localized cure inhibition.

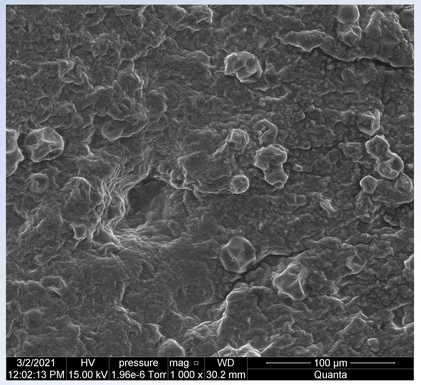

Figure 5 - SEM image of 15% PCM, 85% SR (semi-cured). The surface finish of the sample is much rougher when compared to the 5% and 10% samples, evidently because the SR experienced a reaction to the micro-capsule's contents and was unable to solidify. The sample also appears to have far more embedded micro-capsules; The sample's inability to cure means the micro-capsules are fully coated in a thin layer of the SR, even when on a cut surface.

Conclusion:

The results of these experiments appear to show that the PCM can act as a reaction inhibitor for the silicone rubber, and that a micro-encapsulating material must be carefully selected for its ability to withstand a large range of temperatures. This unfortunately means this particular commercially available and encapsulated PCM is not a strong candidate for use in thermal composites. The future of this experiment lies in creating a lab-synthesized micro-capsule capable of withstanding the temperatures necessary for experimentation. This will be completed in conjunction with the Physical Science's department at Embry-Riddle Aeronautical University. Once a lab encapsulated PCM is successfully created, the thermal composite experiments will resume and the new carrying capacity of the SR will be determined. These samples will undergo SEM imaging, differential scanning calorimeter (DSC) testing, ASTM D412 tensile testing, and shore hardness testing. The goal of these experiments is to determine the viability of utilizing a lab-encapsulated PCM in a shape-stable, SR-based thermal composite.